UNIVERSITI PUTRA MALAYSIA

HETEROSIS AND COMBINING ABILITY STUDIES IN MAIZE (ZEA MAYS L)

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FP 1991 5

HETEROSIS AND COMBINING ABILITY STUDIES IN MAIZE (*Zea mays* L.)

By

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Thesis Submitted in Fulfilment of the Requirements
for the Degree of Doctor of Philosophy
in the Faculty of Agriculture
Universiti Pertanian Malaysia

August, 1991

To the memory of my beloved father

Late Sri. GILLELLA PAPI REDDY

who was the source of inspiration

and encouragement throughout my life

The shattered dream of a corn breeder

Selfed a hundred corn plants,
Put each in a cross;
Selfing without testing,
Means a heavy loss.

Looked around the country,
Found a fertile field,
Used a ten-ten lattice
To find out how they'd yield.

Analyzed the variance,
Wanted Just the best;
Planted only thirty,
Threw away the rest.

Thirty, good in hybrids,
That would be a plenty;
Heavy rains, and lodging;
Then there were twenty.

Still had twenty inbreds
Looking mighty keen;
Hot, humid weather;
Smut left thirteen.

Lucky thirteen inbreds,
Glad to be alive;
Wilt, blight, and aphids;
Then there were five.

So passed the summer,
Full of sweat and tears;
Came then the harvest-
Four had rotten ears.

One sturdy inbred,
All, all alone;
It has no sex appeal,
Can't find a home.

Frederick D. Richey, Knoxville, Tenn.

The use of hybrid varieties has not made the task of plant breeding easier. In corn, the number of successful inbreds is very small in relation to the number developed. In part, the problem has been one of finding parental genotypes that nick well together, a large assignment when four inbred lines are needed for a double-cross hybrid. This prompted the above fictitious experience in an article by Dr. F. D. Richey of the U. S. Department of Agriculture, who has made important contributions to the development of hybrid varieties.

ACKNOWLEDGEMENTS

I wish to express sincere appreciation to my major supervisor Dr. T. C. Yap, Professor of plant breeding, for his counsel, advice and careful supervision throughout the period of graduate study. His helpful suggestions, constructive criticisms and the valuable advice in the preparation of this manuscript are greatly appreciated.

Special appreciation goes to my co-supervisor Dr. Mohd. Khalid Mohd. Nor, Deputy Vice-Chancellor, for his guidance and encouragement throughout this study.

Sincere gratitude is expressed to Dr. P. Raghuram Reddy, Assistant maize breeder, Maize Research Station, Andhra Pradesh Agricultural University, Hyderabad, India, for supplying the seed materials, as well as his technical advice on this study.

Special thanks are due to Mr. Mohd. Said Saad, Lecturer and Madam Salmi bt. Yaacob, Laboratory Assistant, Department of Agronomy and Horticulture for their kind help in one way or another throughout this study.

I am indebted to the staff of field II, Universiti Pertanian Malaysia research area, Serdang, for their help and cooperation in carrying out the field trials. Gratitude is expressed to the Dean, Faculty of Agriculture, Universiti Pertanian Malaysia for providing the facilities and materials necessary to conduct the study.

Finally, I would like to express my indebtedness to my Mother, Smt. G. Durgamma, Brother, Dr. G. Madhava Reddy, and Sister, Smt. S. Vijaya, for providing the financial support to carry out my graduate studies in Malaysia. Last, but not least, I wish to express my gratitude to my wife, Smt. Devi, for providing much needed support, encouragement and understanding throughout the entire period of graduate study.

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Abstract of thesis submitted to the Senate of Universiti Pertanian Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy.

HETEROSIS AND COMBINING ABILITY STUDIES IN MAIZE (*Zea mays* L.)

By

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June, 1989

Supervisor : Professor Dr. T. C. Yap

Faculty : Agriculture

A Diallel cross with 12 parents and resulting 66 F_1's were evaluated for heterosis and combining ability during 1987 and 1988. Differences among genotypes were significant for all characters. Genotype X Year interaction was significant for all traits except ear length.

Average heterosis related to better parent was highest for plot yield, Kernel number per row, ear length and ear diameter. Heterosis was maximum in combinations involving parents of extreme grain type (dent X flint) and/or diverse geographical origin. Degree of heterosis was lowest in crosses of high yielding parents and vice-versa.

SCA was relatively more important for all characters. Data on heterosis was in general agreement with variance component ratios of SCA and GCA and supported conclusions concerning the relative importance of SCA over GCA. Variance components for interactions involving SCA and years were consistently larger suggesting that SCA variance includes a considerable

portion of genotype-environment interaction, apart from non-additive deviations. GCA effects were consistent from year to year while SCA effects were not.

Graphical analysis on diallel data revealed that dominance and epistasis were important for most characters. A tendency of more number of dominant genes were associated with greater performance of characters (except plant and ear height) in the desirable direction.

Most important yield components were ear diameter, ear length, number of kernels per row and 1000-kernel weight. Yield components as well as maturity traits were positively interrelated among themselves, respectively. However, maturity characters were negatively correlated with most traits.

Heritability estimates based on co-variance among relatives were generally in close agreement with estimates based on variance components confirming the results of combining ability analysis.

Heterosis breeding, reciprocal recurrent selection or recurrent selection for SCA may be followed depending on the final objective.

Abstrak tesis yang dikemukan kepada Senat Universiti Pertanian Malaysia sebagai memenuhi syarat untuk ijazah Doktor Falsafah.

KAJIAN HETEROSIS DAN KEUPAYAAN BERGABUNG TANAMAN JAGUNG (*Zea mays* L.)

Oleh

GILLELLA CHINNA REDDY

Jun 1989

Penyelia : Profesor Dr. T. C. Yap

Fakulti : Pertanian

Kacukan dwialel menggunakan 12 induk telah dilakukan dan 66 F_1 yang diperolehi telah dinilai pada tahun 1987 dan 1988 untuk menentukan heterosis dan keupayaan bergabung. Perbezaan antara genotip bermakna bagi semua sifat. Saling-tindak genotip X persekitaran juga bermakna bagi semua sifat kecuali panjang tongkol.

Purata heterosis berbanding induk terbaik adalah tinggi bagi hasil satu plot, bilangan biji per barisan, panjang tongkol dan garis pusat tongkol. Heterosis tertinggi didapati dari kacukan yang melibatkan kombinasi induk yang mempunyai sifat biji yang jauh berbeza (dent X Flint) dan/atau kombinasi induk yang berasal dari kawasan geografi yang berlainan. Heterosis yang rendah pula diperolehi dari kacukan antara induk yang berhasil tinggi dan sebaliknya.

SCA penting bagi semua sifat. Data heterosis menunjukkan persetujuan dengan kadar komponen varians SCA dan GCA, dan ini menyokong kesimpulan bahawa SCA lebih penting dari GCA. Komponen varians untuk saling tindak SCA dan tahun sentiasa tinggi, menunjukkan varians SCA mengandungi sebahagian dari saling tindak genotip-persekitaran selain dari kesan perubahan tak menambah.

Analisis grafik data dwialel pula mendapati dominan dan epistasis penting untuk semua sifat. Kemungkinannya terdapat banyak gen dominan terlibat dalam prestasi tinggi kearah yang dikehendaki pada semua sifat (kecuali tinggi pokok dan panjang tongkol).

Komponen hasil terpenting ialah garis pusat tongkol, panjang tongkol, bilangan biji per baris, dan berat 1000 biji. Komponen hasil dan sifat kematangan berkait antara satu sama lain secara positif. Walau bagaimanapun, sifat kematangan berkorelasi negatif dengan semua sifat lain.

Anggaran keterwarisan menggunakan kovarians antara relatif dan anggaran menggunakan komponen varians adalah sama, ini membuktikan kesahihan keputusan dari analisis keupayaan bergabung.

Membiakbaka heterosis, pemilihan berulang salingan atau pemilihan berulang untuk SCA boleh digunakan bergantung kepada objektif akhir.

CHAPTER I

INTRODUCTION

Maize is one of the most important cereals of the world grown on an area of 131.475 million hectares, with a production of 480.609 million metric tonnes. In terms of world acreage and production, the United States of America stands first (28 million hectares and with a production of 209.632 million metric tonnes) accounting to 21.30 and 43.62 percent of total world acreage and production, respectively (FAO, 1986). In Malaysia, maize is grown on an area of approximately 15,000 hectares, and the production accounting for only two percent of the total local requirement.

The maize plant is native to the tropical America and is relatively a recent introduction to South and South East Asia. There is no record as to when the Local Flint variety was introduced into Malaysia, but according to Burkill (1966) maize might have been introduced into Malaysia through Malacca during the Portuguese and Dutch occupations. The cultivars grown here are mainly sweet corn, which is used for human consumption. With respect to the starchy maize, which is mainly used for animal feeds, the demand is more than 1.21 million tonnes costing about M$ 324.73 million of foreign exchange in 1986 (Malaysia External Trade Statistics, 1986). Most of the starchy maize consumed in Malaysia is for animal feed and is imported annually from other maize growing countries. The demand for this crop is on the increase in recent years due to the rapid expansion of the livestock industry. To cope with the ever increasing demand and to cut down the import, Malaysia should increase the production by developing more land for maize cultivation and by planting highly productive hybrids with improved farm practices.

Hybrid corn is the classical example of success of science of genetics and is one of the most important advances in the field of agriculture in the past century. Exploitation of heterosis is a quick, cheap and easy method of attaining maximum yields. An understanding of the fundamental nature of gene action involved in the phenomenon of heterosis and in the inheritance of quantitative characters, in general, is of primary interest.

One of the important methods of upgrading the population performance is through introduction of the effects of desirable genes from exotic sources so that the progeny population is able to improve stage by stage. This process is sometimes known as 'genetic reconstruction'. The introduction of the effects of exotic genes can be done only through hybridisation - natural or conscious. The problem also remains whether, after hybridisation the effects of the genes would get incorporated into the progeny population or not. It would be desirable therefore, if one can devise a method to study whether favourable gene incorporation can be obtained by hybridisation in a particular material. In other words, the problem is to understand how best two parents can combine to produce a superior offspring population, i.e., to understand the combining ability of parents - general and specific. General combining ability (GCA) is assumed to be primarily a measure of additive gene action and specific combining ability (SCA) the deviations from additivity. A number of methods using the second order statistics have been proposed by several workers to estimate genetic variances which reflect the types of gene effects involved (Jinks and Hayman, 1953; Jinks, 1954; Hayman, 1954b; Griffing, 1956b; Cockerham, 1963; Gardner and Eberhart, 1966). The relative magnitude of different kinds of genetic variances, the types of gene effects involved in controlling quantitative characters and their interactions with different environment is important to the breeder, because they influence the type of the breeding programme to be employed and the success to be expected from the programme.

Knowledge of stability of gene action may be useful in a general way in emphasizing the need to evaluate any genetic material in different environment. Specific instances of stability may be less useful or even misleading. An ideal hybrid should be expected to produce stable yields under wide environmental conditions. Hybrid response to different environments can be measured statistically as hybrid by environment interaction or more specifically as a genotype by environment interaction.

Within the above framework, the objectives of the present study were to:

1) determine the extent of heterosis present in different crosses for each of the 12 characters studied;
2) determine the role of genetic diversity in heterosis;
3) determine the relative importance of additive versus non-additive genetic variance for each of the 12 characters studied;
4) determine the stability of types of genetic variances between years;
5) identify parents with a greater number of dominant genes for each of the 12 characters studied;
6) determine phenotypic associations among characters; and
7) determine the heritability of each character for planning an efficient breeding programme.

CHAPTER II

REVIEW OF LITERATURE

Heterosis

Heterosis is not a newly discovered phenomenon but has been known since the art of hybridization came into existence. Kölreuter (1766) and other early hybridisers were quite aware of its presence in plants. Mendel (1865) observed its manifestation in his pea crosses. Charles Darwin (1876) had also concluded that the inbreeding in plants would result in the deterioration of vigour and that crossing would restore hybrid vigour. In maize the first studies on artificial hybridisation were those reported by Beal in the period of 1877 - 1882. He had stated that the yields of hybrids (between different open-pollinated varieties) were larger than those of parents by as much as 40 percent.

Following the rediscovery of Mendel's laws in 1900, due interest has been paid to the systematic work of studying the phenomenon of heterosis. Independent studies started in 1905 by East at the Connecticut Agricultural Experiment Station and by Shull (1908) at Cold Spring Harbour, on self- and cross-pollination in maize have led to a better understanding of the problem of heterosis. Shull carried out the first experimental proof of inbreeding depression and restoration of vigour in corn. East also studied the effect of selfing and crossing on tobacco, a self-pollinated plant. East and Hayes, (1912) reported the effects of self-fertilization in detail and emphasized the probable practical value of heterozygosis.

The term 'heterosis' was first proposed by Shull (1914) to avoid the implication that all genotypic differences which stimulate cell-division, growth and other physiological causes and as a substitute for the term 'stimulus of heterozygosity' and other phrases then in use. Shull clearly explained the meaning of the expression 'heterosis concept' as follows :

"I suggest that it is the interpretation of increased vigour, size, fruitfulness, speed of development, resistance to diseases and insect pests, or to climatic rigours of any kind manifested by crossbred organisms as compared with corresponding inbreds as the specific results of unlikeness in the constitutions of the uniting parental gametes"

In classical genetics, heterosis involves the increased vigour of the F_1 generation over that of the greater parent, whereas, in statistical or quantitative genetics, the criterion of heterosis is the superiority of the F_1 over the average of the two parents. From practical point of view, however, amount of heterosis observed in F_1 is important only when the F_1 is superior to the better parent. This type of heterosis is also known as heterobeltiosis.

The phenomenon of heterosis can be explained on the basis of genetical and physiological causes.

Genetical Basis of Heterosis: Various theories have been advanced from time to time to explain heterosis, but none of the hypotheses have succeeded to clarify all the intricacies of the problem and it is considered that heterosis is not due to a single genetical cause. There are at present two principal hypotheses concerning the genetical basis of heterosis, viz., Dominance Hypothesis and Overdominance Hypothesis.

Dominance Hypothesis: Davenport (1908), Bruce (1910) on mathematical grounds and Keeble and Pellew (1910) from observed vigour in F_1 hybrids of peas were the first to postulate the dominance hypothesis, that the increase of vigour in a hybrid resulted from the complementary and cumulative actions of dominant genes. Most individuals in an allogamous population carry deleterious recessive genes concealed in the heterozygous condition. The increase in the frequency of the genotypes homozygous for deleterious recessives in inbreeding leads to vigour deterioration, and vigour is restored by crossing of inbred lines which is due to the increase of the heterozygosity for many dominant complementary genes.

Objections to this hypothesis were made largely on two grounds. First, why no true breeding homozygous lines were obtained in succeeding generations (Shull, 1911; East and Hayes, 1912). If vigour was not a product of heterozygosity as such, it would be possible by selection to obtain individuals which are homozygous for all favourable dominant genes. The second objection is why heterotic characters are symmetrically distributed rather than skewed (Emerson and East, 1913). If heterosis is due to dominance of independent factors, the F_1 distribution curve should be skewed rather than symmetrical, because the dominant and recessive genes would be distributed according to the binomial expansion $(3/4 + 1/4)^n$, where, n is the number of loci involved.

Jones (1917) in his modified theory entitled "Dominance of Linked Genes" pointed out that a dominant gene might be tightly linked with some detrimental recessive genes to prevent isolation of an individual with all dominant genes. Later, Collins (1921) showed that with a large number of genes involved, regardless of linkage, the skewed distribution could not be obtained.

Overdominance Hypothesis: The concept of this hypothesis was given independently by Shull (1908) and East (1908) on the supposition that heterozygote is superior to either homozygotes and the hybrid vigour increases in proportion to the amount of heterozygosity. To the same idea,